

Physics Working Group

Summary

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HEMC Physics Opportunities

1. What is the new physics?
2. What are the theoretical motivations?
What theoretical frameworks does this fit into?
3. How do the LHC + LC + other expts provide evidence/hints
 - of this new physics?
 - of the energy scale of this new physics?
4. What are the experimental signatures at a HEMC?
What do you need to measure? Are there backgrounds?
Do you need/take advantage of
 - small beam energy spread
 - polarization
 - radiative return
 - forward coverage
 - heavy flavor tagging
 - good hadronic calorimetry
5. What is the minimal useful luminosity?
6. What is the most likely relevant energy scale/scales.
7. References

HEMCPO #1

T. Rizzo

1. Kaluza-Klein excitations of SM gauge bosons
2. Extra dimensions, SM-on-a-brane, low string scale
low effective Planck scale, accelerated gauge coupling unification.
3. (i) First KK states of $\gamma/Z/W$ are observable at LHC in Drell-Yan. KK gluon is marginal at best.
(ii) LHC can't distinguish ~~this~~ ^{degenerate γ/Z KK state,} from a Z' , LC can rule out a Z'
(iii) From mass of lowest KK can compute higher KK's in models.
4. Measure as many "EWC" observables as possible
 - unpolarized
masses
 - polarized
ALR
 - A_{FB}^{pol}
 - A_{FB}
5. Compute \mathcal{L} versus \sqrt{s} $10^{34} - 10^{36}$ GeV. need to measure it.
6. Start with highest practical \sqrt{s} ; find KK peaks by radiative return, then run on each pole.
 ~ 10 TeV may be good enough
7. References: Rizzo, Rizzo+Wells, Nath et al, Antoniadis, etc.

1. WTC spectroscopy

HEMC production of ρ_T^0 and w_T ground states
plus radial/orbital excitations

2. Theory motivation and framework

Walking technicolor needed to avoid large FCNC in ET

Δ_{TC} runs very slowly

\Rightarrow spectral functions are not saturated by low-lying resonances

\Rightarrow a "tower" of $\rho_T^{0\pm}$, w_T , etc extending up to 100-500 TeV

3. How do LHC + LC + ... provide evidence?

In minimal TC lightest ρ_T, w_T are 1-2 TeV
in nonminimal TC, as low as 200 GeV

$$\rho_T^0 \rightarrow W_L^+ W_L^- \quad \text{visible at LHC up to}$$

$$\rho_T^{\pm} \rightarrow W_L^{\pm} Z^0 \quad M_{\rho_T} \sim 1 \text{ to } 1.5 \text{ TeV}$$

4. Experimental Signatures at HEMC.

minimal $\rho_T^0 \rightarrow W_L^+ W_L^- + \text{more} (?)$

TC: $W_T \rightarrow W_L^+ W_L^- Z_L^0 + \text{more} (?)$

nonminimal
TC: $\rho_T^0 \rightarrow W^\pm \pi_T^\mp \xrightarrow{\text{L}} b\bar{c}, \dots$
 $\rightarrow \gamma \pi_T^0 \xrightarrow{\text{L}} b\bar{b}, gg$

$W_T^0 \rightarrow \gamma \pi_T^0 \xrightarrow{\text{L}} b\bar{b}, gg$

Backgrounds:
 $w^+ w^-$
 zz
 multijet

Requirement	minimal TC	nonminimal TC
Small E _{beam} spread	no	no
polarization	no	no
radiative return	yes	yes
forward coverage	no	no
heavy flavor tagging	no	yes
good HCAL	yes	yes

$$5. \quad \mathcal{L}_{\min} \sim 10^{33} \text{ cm}^{-2} \text{s}^{-1} \left(\frac{\sqrt{s}}{1-3 \text{ TeV}} \right)^2$$

6. Energy scale 1-100 TeV

1. SUSY messengers

2. Theory motivation

Gauge-mediated SUSY models have heavy vector-like "messenger" particles

\Rightarrow vector-like heavy "quarks" Q_i
 "charged leptons" E_i
 "neutrinos" N_i

+ their scalar superpartners

$----- \tilde{Q}_i$

could be as
 light as ~ 10 TeV
 or much heavier

$Q'_i ----- \tilde{Q}'_i$

3. At LHC + LC + Tevatron:

- discover superpartners
 - verify that it is gauge-mediated SUSY from distinctive γ signatures
 - measure neutralino decay length + superpartner spectrum
- \Rightarrow compute upper bound on messenger masses

4. Experimental signatures at HEMC

Fermion messengers decay

→ scalar messengers + gauginos

Scalar messengers don't decay inside the detector

- charged E_i 's look like very heavy muons
heavily ionizing
TOF
- Q_i 's hadronize
- N_i 's are missing energy

5/6 $\sim 10^{36}$ fb^{-1} O.K.

minimum \sqrt{s} determined from LHC/LC measurements,
could be 10 TeV
could be 100 TeV
could be > 100 TeV

HEMCPO #4

M. Berger

- Flavor changing effects in slepton production

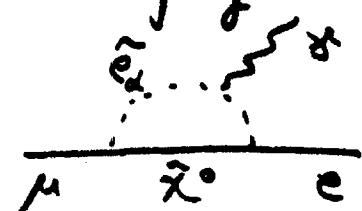
$$\tilde{e}_L: W_{Li}^* \bar{e}_{L\alpha} \tilde{\chi}^0 + \tilde{e}_{Lj}^* W_{Lj\alpha} \bar{\tilde{\chi}}^0 e_{L\alpha} + (L \rightarrow R)$$

W = flavor mixing matrix

- Supersymmetry, lepton flavor violation, GUT scale boundary conditions

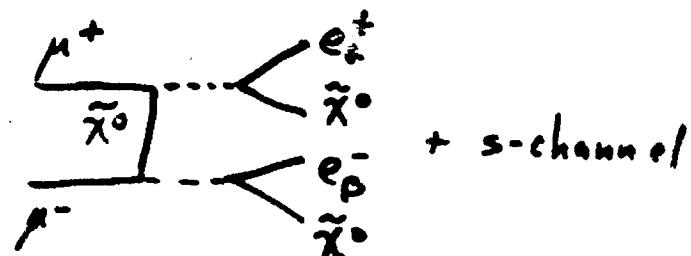
- Rare processes also constrain rare flavor-changing

$$\begin{aligned} B(\mu \rightarrow e \gamma) &< 4.9 \times 10^{-11} & \text{MEGA} \\ B(\tau \rightarrow \mu \gamma) &\leq 2.9 \times 10^{-6} \\ B(\tau \rightarrow e \gamma) &\leq 2.7 \times 10^{-6} \end{aligned} \quad \left. \begin{array}{l} \text{MEGA} \\ \text{CLEO} \end{array} \right\}$$



- Signals at HEMC

$$\mu^+ \mu^- \rightarrow e_\alpha^+ e_\beta^- \tilde{\chi}^0 \tilde{\chi}^0$$



Backgrounds: WW

$$W\gamma\mu$$

$$\sigma \propto W_{i\alpha} W_{i\beta}^* W_{j\alpha}^* W_{j\beta}$$

$$\text{CP violation: } \sigma_{e_\alpha^+ e_\beta^-} \neq \sigma_{e_\beta^- e_\alpha^+} \Rightarrow \text{Im}[W_{i\alpha} W_{i\beta}^* W_{j\alpha}^* W_{j\beta}] \neq 0$$

- Requires calculation of σ , backgrounds

Scaling up study at Fermilab workshop ~ few (attobarns)⁻¹

- More luminosity \rightarrow better constraint
pair produce sleptons, polarization to reduce BG's.

- Arkani-Hamed, Cheng, Fong, Hall
Bowser-Chao, Keung

General Observations

1. There are many new physics scenarios that make a HEMC look exciting.
2. It is essential to use LHC + other expts to get an indication of what you will find at 10-100 TeV
3. In most scenarios you would build the 10 TeV HEMC and be happy.
For a few cases (e.g. SUSY messengers) you would want to go directly to a >10 TeV machine.
4. More detailed studies can address detector/machine issues